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D. M. Bauman and A. E. Jensen

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The Department of Defense (DoD) is currently experiencing extremely serious problems with Software Engineering. As weapons systems become increasingly more dependent upon the software programs which they employ, it becomes evermore apparent that DoD projects are consistently late and over budget because of software. To this end, software has become the dominant risk to cost and schedule and has caused the demise of more than a few DoD development projects.

The DoD repeatedly demonstrates requisite experience to efficiently manage the development of hardware. Hardware development projects, for which the DoD readily implements tried and proven practices to systematically address all aspects of the development, are relatively risk free at their onset.

Software development projects, on the other hand, are oftentimes initiated without the benefit of similarly institutionalized methodologies and practices. Because an understanding of proper Software Engineering practice is only now developing, standard, well-accepted measures do not yet exist. The DoD seems only to be scratching at the surface of state-of-the-art software engineering and herein lies the basis of the problem.

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D. M. Bauman	(619) 553–4222	Code 833

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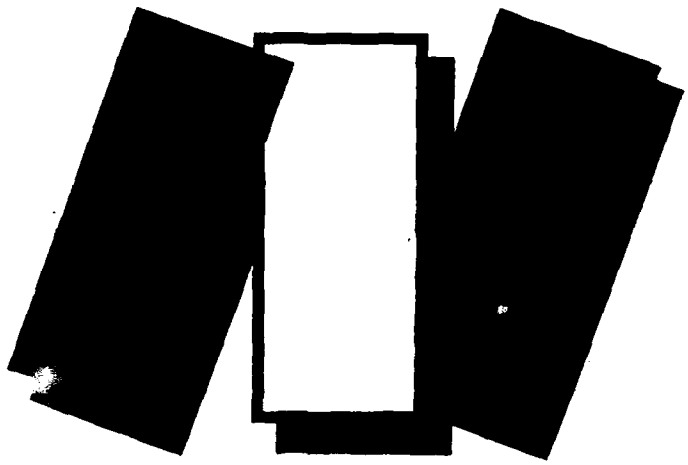

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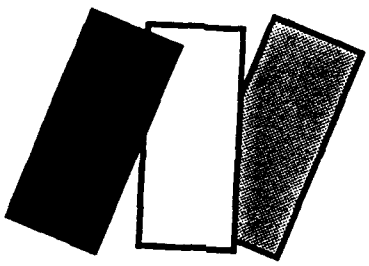

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We invite you to take advantage of this publication, which expands upon Symposium presentations and introduces new authors and topics. Please note that the views expressed are those of the authors and do not necessarily reflect the views of the organization with which they are associated.

CONTRACTING IN THE SOFTWARE ENGINEERING CRISIS

Mr. Dennis M. Bauman and Mr. Albert E. Jensen, The Naval Ocean Systems Center

ABSTRACT

The Department of Defense (DoD) is currently experiencing extremely serious problems with Software Engineering. As weapons systems become increasingly more dependent upon the software programs which they employ, it becomes evermore apparent that DoD projects are consistently late and over budget because of software. To this end, software has become the dominant risk to cost and schedule and has caused the demise of more than a few DoD development projects.

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INTRODUCTION

Experience at the Naval Ocean Systems Center has demonstrated that Software Engineering plays an ever increasing, key role in our ability to be successful, responsive to sponsor requirements, and competitive. Recent innovations in the Software Engineering discipline promise to reduce risks associated with this type of development if we are able to effectively adopt and utilize them. The Naval Ocean Systems Center Technical Director has made a major commitment of Center resources by establishing the Software Engineering Process Office, and implementing plans to eventually reach higher levels of process maturity. Only through proactive measures such as this can we, as a Center, continue to meet our mission in this vital area. In fact, the Software Engineering Crisis threatens our reputation and thus, our continued work in Navy systems.

The approach adopted by the Technical Director only addresses part of the problem, perhaps a minor part of the problem. Most of the software developed at this Center is developed by support contractors. The average locally based support contractor is incapable, without substantial initial and sustained investment, and sharply increased skill levels, of performing the state-of-the-art Software Engineering needed to reduce the risks associated with software

development projects. In order for the Naval Ocean Systems Center to be able to take advantage of these new Software Engineering Processes, our support contractors must be motivated to become partners with us by adopting the same philosophies and taking similar proactive measures to improve our Software Engineering capabilities. Neither can do it alone. As contractors improve their ability to meet our needs for quality software, our ability to serve the national interest will be improved by awarding contracts to those with the best capability. To provide this motivation, we must give our contractors an opportunity to compete with one another with regard to modern Software Engineering, and we therefore need the tools with which to measure Software Engineering competency. We have them.

CAPABILITY ASSESSMENT

The Software Engineering Institute (SEI) is a federally funded research and development center, formed in 1984 in response to the need for advances across all phases of the Software Engineering process. The SEI is a unit of Carnegie Mellon University, under contract with the DoD. Its mission, based upon an assumption that sound engineering processes lead to quality software, is to influence rapid improvement of the quality of operational software in mission-critical computer systems, to accelerate the reduction to practice of modern Software Engineering techniques and methods, to promulgate the use of modern techniques and methods throughout the mission-critical systems community, and to establish standards of excellence for Software Engineering practice.

ASSESSMENT TOOL

The SEI Technical Report "A Method for Assessing the Software Engineering Capability of Contractors" dated September 1987 provides us with a tool, as its title implies, with which to assess the Software Engineering Process Maturity of our contractors. We found that the SEI assessment instrument can be used to facilitate objective and consistent assessments of the ability of potential DoD contractors to develop software in accordance with modern Software Engineering methods. This assessment instrument is basically a questionnaire calling only for yes or no answers to questions based on the following premises:

- The quality of a software product stems, in large part, from the quality of the process used to create it.

- Software engineering is a process that can be managed, measured, and progressively improved.

- The quality of a software process is affected by the technology used to support it.

- The level of technology used in software engineering should be appropriate to the maturity of the process.

- Software products developed by contractors for DoD use are acquired under contracts invoking DOD-STD-2167A, Defense System Software Development, as tailored for each contract.

The SEI questionnaire is arranged so that the capability to perform software engineering is divided into three areas:

- Organization and resource management,

- Software engineering process and its management, and

- Tools and technology.

To provide a structure for assessment, five levels of process maturity and two stages of technology advancement have been postulated:

Process Maturity Levels:

1 - Initial: The initial environment has ill-defined procedures and controls. The organization does not consistently apply software engineering management to the process, nor does it use modern tools and technology. Level 1 organizations may have serious cost and schedule problems.

2 - Repeatable: At Level 2, the organization has generally learned to manage costs and schedules, and the process is now repeatable. The organization uses standard methods and practices for managing software development activities such as cost and estimating, scheduling, requirements changes, code changes, and status reviews.

3 - Defined: In Level 3, the process is well characterized and reasonably well understood. The organization defines its process in terms of software engineering standards and methods, and it has made a series of organizational and methodological improvements. These specifically include design and code reviews, training programs for programmers and review leaders, and increased organizational focus on software engineering. A major improvement in this phase is the establishment and staffing of a Software Engineering Process Group that focuses on the software engineering process and the adequacy with which it is implemented.

4 - Managed: In Level 4, the process is not only understood but it is quantified, measured, and reasonably well controlled. The organization typically bases its operating decisions on quantitative process data, and conducts extensive analyses of the data gathered during software engineering reviews and tests. Tools are used increasingly to control and manage the design process as well as to support data gathering and analysis. The organization is learning to project expected errors with reasonable accuracy.

5 - Optimized: At Level 5, organizations have not only achieved a high degree of control over their process, they have a major focus on improving and optimizing its operation. This includes more sophisticated analyses of the error and cost data gathered during the process as well as the introduction of comprehensive error cause analysis and prevention studies. The data on the process are used iteratively to improve the process and achieve optimum performance.

Software Technology Stages:

A - Inefficient: Multiple implementations may be avaialble and the practice may be in widespread use, but the technology is no longer effective. An organization that primarily employs inefficient software development technology is likely to be ineffective in developing software. Moreover, at this technology stage some important software engineering practices are not practical in large complex developments.

B - Basic: Multiple implementations are available, and they have been demonstrated to be effective. An organization that primarily employs basic software development technologies is likely to be moderately effective and, depending upon the maturity of its process, reasonably consistent in its performance.

SEI Guidance

The SEI offers guidance for assessing the capability of contractors, using the assessment instrument. Such assessments may be conducted either in the pre-solicitation qualification process, in the formal source selection process, or both. This Software Capability Evaluation (SCE) method should be used to augment the many steps currently involved in source selection. However, the effectiveness of a SCE is critically dependent on the process used in the assessment and on the background and training of the personnel conducting it. Information contained in the document itself providesthe SEI guidance for its use:

- When used as part of the formal DoD systems acquisition process, the questions are furnished, for information purposes, to potential bidders with the Request for Proposal (RFP).

- Answers to the assessment questions are not submitted with the proposal, but are provided to an assessment team that visits each competing contractor during the proposal evaluation period.

- Several days of classroom instruction must be afforded each of the competing contractors, to review the assessment questionnaire in detail and discuss the materials and support tools that should be available to demonstrate performance for each question.

- The Government assessment team will visit each competing contractor during the evaluation period. Several major software development projects, as agreed to by the contractor and the assessment team, will be assessed. A period of 3 to 4 days is needed to review the questions, obtain and discuss back-up material, demonstrate support tools, and present conclusions. A single assessment team should be used to visit all of the competing firms to assure consistent interpretation of both the questions and the results.

- The assessment team must have a mix of talents. A minimum of four experienced professionals are required, including those knowledgeable in the software development process, the technology, the application area, and the specific procurement. All team members must have been trained in the SEI SCE process. This training is available in a 3-day course of instruction offered by the SEI at Carnegie Mellon University.

- At the conclusion of each assessment, the contractor's management is informed of the findings and given an opportunity to offer evidence to refute any disputed findings and to explain their plans for process improvement.

- The results of each assessment are made available to the Source Selection officials for consideration prior to contract award.

Following the SEI guidance, as above, will provide a thorough assessment of the software engineering capabilities and

process maturity of all competing contractors. However, the following points should be considered:

- Costs involved with the above implementation could soar. Training and on-site assessment for a single contractor may be well in excess of $20,000, depending upon location, i.e., local contractor, or one which is located somewhere between San Diego and the East Coast. Furthermore, there is an average of seven respondents to every solicitation issued by the Naval Ocean Systems Center.

- The above implementation process could lead to contract award to an unqualified firm if none of the competing contractors are at the software process maturity level required to support the requirements of the contract.

EMERGENT NEED

In the light of the current Communications Department and Contracts policy to move away from the large, omnibus type contracts to smaller and more project specific contracts, we in the Operational Systems Branch, Code 833, of the Submarine Communications Division were faced with an emergent need for contract support for several of our projects. We determined that the contract support needed covered a broad range of disciplines, but that the predominant need was for efficient software engineering which would enable significant risk reduction in current and future development projects. More specifically, our need was determined to be contractor support which could immediately respond with software engineering capability commensurate with SEI Level 2, or higher process maturity. We decided to invoke the SEI Software Capability Evaluation (SCE) method in a solicitation and source selection process.

OUR APPROACH

Since the scope of the support contract would cover a wide range of disciplines, We were concerned that a single contractor, capable of modern software engineering practices, may not have the necessary background and experience needed to adequately support the remaining requirements. For this reason, we prepared a synopsis for publication in the Commerce Business Daily (CBD) which encouraged contractor teaming.

Because of the considerations above, i.e., high cost and the possibility of gaining unqualified contractor support, the SEI assessment methodology had to be tailored. Therefore, we developed a Source Selection Plan which provided the necessary tailoring to the SEI guidance for using the assessment document, and clearly stated the additional requirements to be incorporated into the solicitation:

- A prerequisite that any respondent to the RFP demonstrate that they are currently performing software engineering practices at the SEI Level 2, or higher process maturity, was established.

- To determine the level of software process maturity, the SEI assessment document was included with the RFP; each offeror was required to perform a "self-assessment". Results of the self-assessment were submitted with the proposal; however, this was not used in conjunction with the technical evaluation for scoring purposes.

- Technical and cost proposals were evaluated to determine the relative ranking of all offers with respect to the "greatest value to the Government". However, prior to contract award, the Government did perform an on-site validation of the contractor's SEI self-assessment. The validation was performed by a qualified, SEI trained team of professionals. The RFP stated that in the event that a contractor in line for award, technical and cost considered, failed to demonstrate a current SEI Level 2 or higher process maturity, the next offeror in line for award would undergo this on-site validation, and so forth until the otherwise qualified contractor, meeting the prerequisite SEI level of process maturity was determined.

To strengthen the technical proposals, and to ensure that the selected contractor would continue to perform at the leading edge of software engineering, we required each competing contractor to submit a "Software Standards and Procedures Plan" as a part of their proposal. In the RFP, we specified the criteria to be presented in the plan. This criteria consisted simply of those individual elements commensurate with SEI Level 2 process maturity. In order to ensure compliance, this plan was heavily weighted within the overall technical evaluation. And finally, we required that this plan become binding upon the contractor for all software work to be performed under the contract.

The importance of the technical proposals was established in the source selection process by setting a relatively high technical to cost ratio in the source selection plan. Our approach to contractor source selection for work on "Airborne Submarine Communications" projects was successful in gaining the level of engineering competence needed. By design, our approach led to contract award only to a qualified, SEI Level 2 or higher firm. It did; however, exclude from competition, any firm which may be presently SEI Level 1 albeit very close to SEI Level 2 performance. We found our approach to be highly cost effective since we needed to conduct only one on-site validation of the SEI self-assessment. Our approach readily demonstrated our intention, as evidenced by the unusual number of contractor questions, cries of unfairness, and one formal protest, to insure that the contract award be competed primarily on technical issues. After all, the SEI Level 2 process maturity has not previously been a prerequisite to contract award. Our approach to contractor selection provided the following experiences:

- We received four proposals to our solicitation, each representing contractor teaming arrangements with a single prime contractor.

- One offer was eliminated initially, based on a very weak technical proposal. This left three offers in the technically competitive range.

- Evaluation of three Best and Final Offers reinforced the original ranking; however, eliminated one offeror from the technically competitive range.

- The contractor in line for award, based on the "Greatest Value to the Government" as determined by technical and cost evaluations, was also determined to be currently operating at the prerequisite level of software process maturity.

- There was one formal protest which was withdrawn following technical debriefings and clarification of the Government selection process.

CONCLUSION

In conclusion, the SEI guidance for using their Technical Report, "A Method for Assessing the Software Engineering Capability of Contractors", dated September 1987, can be extremely time consuming, prohibitively expensive, and could lead to contract award to an unqualified firm. The Naval Ocean Systems Center's approach to implementing this assessment instrument in the solicitation and source selection process offers expediency, provides cost control over the process, and excludes all potentially unqualified offerors. However, the risk of contractor protest should be considered under the latter approach.